///*flood.landscape.autopsy*: Digital Post-Disaster Retrospection for Sustainable Design Decision Making

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Abstract: The moment after a natural disaster is a window of time that can be used to adapt-to-climate (change), but this opportunity is in many cases demonstrably wasted. The paper is devoted to the question of how can the collective amnesia that sets in shortly after natural disasters be prevented. After a disaster, amnesia leads people to forget about what primarily should be designed and built. For example, following a flood, it is not enough to understand and visualize relevant facts, such as the highest level of the flood and so forth. To avoid repeating mistakes that have been made before, elements of the drama and its symptoms like shock, helplessness, chaos, fear, etc., should be included in the retrospection of the catastrophic event. In order to avoid the unsustainable cycle of amnesia, we work on ways of pairing the hard facts of the natural environment with the emotional cognition of the affected human beings. These two layers are presented in the context of planning communication with experts, laypeople, and decision-makers. The aim is to avoid an unreasonable reconstruction reflex, and facilitate sustainable progress in the form of environmental and climate change adaptation. Digital instruments and approaches – some of them standard, some of them rather unorthodox – are considered suitable means of drawing nearer to such an ambitious goal.

Keywords: Post-disaster analysis, climate change adaptation, landscape design

1 A Recent Flood Case

The paper title is a reference to the digital application *what3words* that divides the world into a global grid of 57 trillion three-meter squares and allocates each square a combination of three words (WHAT3WORDS.COM 2022). On the evening of July 14th, 2021, one of the authors tried to send the *what3words* location of a family of four in emergency to aerial rescue.

Fig. 1: Ahrbrück, 14 July 2021. Left: A family of four sitting astride the roof ridge of their collapsing house. Soon after, the houses were torn away by the flood. Right: The next day (Photos: J. Rekittke, 2021).

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They were sitting astride the roof of their collapsing house, in the middle of the tsunami-like flood of the Ahr River in West Germany (Figure 1).

Minutes later, the house was torn away and two of the four on the roof died. Then, the neighboring house collapsed killing another family of five. The Ahr River flood event is a concrete example which we use for the paper to establish and explain the proposed approach. The academic claim of the work is aimed at ubiquity. Although our previous work featured experiences with urban floodplains (REKITTKE 2013), we had not yet been on the ground at the exact moment extreme flooding occurred. In the case of the Ahr valley disaster, one of us was. This circumstance created an accidental opportunity of a continuous insider view into the development of the flooding itself, as well as post-disaster measures. In meteorological terminology, the Ahr River flood was the result of *very pronounced heavy regional rainfall events, in connection with the low-pressure system 'Bernd', especially in the period from July 12th to July 15th 2021.* Heavy precipitation of varying durations occurred during the event period. In addition, the soil moisture situation was relevant. In the regions of Rhineland-Palatinate and South Westphalia, the soils could hardly absorb any additional water (GERMAN WEATHER SERVICE 2021). A diagram (Figure 2), based on data of the Flood Reporting Service Rhineland-Palatinate derived from the water level gauge in the city of Altenahr, before the gauge was torn away by floodwaters at a level of 5.75 meters, illustrates the unprecedented nature of the event (SWR AKTUELL 2021a). Numerous large trees were uprooted by the flood wave and clogged bridge channels, leading to impoundment and flow changes that made the situation worse. Meanwhile, a collective reconstruction reaction led to breathtakingly fast rebuilding activity. EUR 30 billion were released by the government for compensation and repair of private damage. However, problematically, such a quick response does not necessarily lead to sustainable design and building.

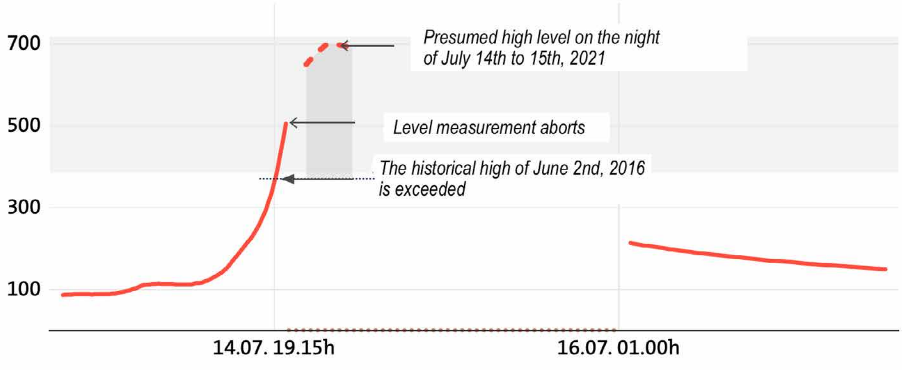

Fig. 2: Rapid rise in level of the Ahr (gauge in Altenahr) on 14 July 2021. At 19:15 h, the flood wave passed the historic mark of 3.21 m. At 5.75 m gauge height, the flash floods tore away the measuring device (Graphic: SWRDATA 2021, translated).

A combined analysis (SCHMID-JOHANNSEN, LANG & HEILIGER 2021) based on data from: a) rapid mapping by the European COPERNICUS Emergency Management Service (COPERNICUS EMERGENCY MANAGEMENT SERVICE 2021); b) the Flood Reporting Service by the State Office for the Environment of the German Federal Land Rhineland-Palatinate; and c) the Supervision and Service Directorate (ADD) of the German Federal Land Rhineland-Palatinate (ADD 2021), produced the following facts and figures. 133 flood-induced deaths and 766 injured were counted in the Ahr valley. The Supervision and Service Directorate Rhineland-Palatinate assumes that of the 56,000 people living along the Ahr in the Ahrweiler district, about 42,000 people were affected. Of these, at least 17,000 immediately lost their belongings or faced considerable damage (COPERNICUS EMERGENCY MANAGEMENT SERVICE 2021). Of the 4,200 buildings along the Ahr, more than 3,000 buildings have been damaged, which corresponds to more than 70 percent of all buildings. The flood destroyed 467 buildings. Of the 179.7 kilometers of roads, bridges and paths (Figure 3) in the Ahr valley, more than 73 kilometres showed signs of damage (SCHMID-JOHANNSEN, LANG & HEILIGER 2021).

Fig. 3: Federal Road tunnel near Altenahr after the flood event in mid-July 2021 (Photo: picture alliance/dpa/Thomas Frey, 2021)

2 Post-disaster Landscape Autopsy

We take an academic approach to the incredibly large post-flood design task, without time and cost pressure. Before planning, designing or building anything, we look in retrospect, like pathologists doing an autopsy rather than designers who strive for immediate action and new creation. Our approach is hybrid. We witnessed what happened during the disaster and, at the same time, we command digital tools suitable for adding to the act of autopsy. Our hypothesis states that without a thorough review of a disaster, economically, environmentally, and ecologically sensible decisions become unlikely. Disasters like floods can be perceived objectively and subjectively. Subjectively, the event can be privileged or erased according to a sense of selective memory or collective amnesia (HILHORST 2004). The post-event evaluations, instructions, and actions after the Ahr flood in 2021, seemingly politically rather than scientifically motivated, are an impressive example of such subjectivity and amnesia.

Although more than 3,000 buildings along the Ahr have been damaged, and at least 467 buildings destroyed in their entirety (SCHMID-JOHANNSEN, LANG & HEILIGER 2021), the government recently announced that only 34 buildings in the Ahr valley should "not" be rebuilt (LUEG 2021). This ratio of 34 to 467, is remarkable in times of climate change debate and postulated climate change adaptation strategy development. We use the term landscape autopsy on the basis of its etymological origin. The Greek word autopsia, means the act of seeing for oneself (ENCYCLOPEDIA BRITANNICA 2021). We intend to demonstrate that post-disaster analysis and subsequent planning and design should not only be based on documents of high abstraction level, like maps with zones and lines, and wording of laws, but it should also incorporate what people have seen themselves. "An autopsy may be performed to determine the cause of death, to observe the effects of disease, and to establish the evolution and mechanisms of disease processes" (ibid.). When time and accuracy are invested for an autopsy, the temptation to give in to amnesia and repeat the mistakes of the past may be lessened. Pathologists cogitate about things that may have happened when the person under their scalpel was still alive. We combine, in a direct way, footage that was produced during the flood, with maps, facts, and figures that were produced before and after the flood. In so doing, we fill the common gap between reality, recollection, and forward planning with evidence that is supposed to trigger cogitation – like in an autopsy. We advocate, that such process should precede any planning or rebuilding after any flood event of the future. Making the same mistakes again, comes with a high price. The 2021 flood disaster in the Ahr valley, for example, is likely to become one of the most expensive insurance claims in Germany (KROHN 2021).

3 Strata of Evidence

Our investigation area is formed by the town of Ahrbrück and the districts of Ahrbrück, Brück and Pützfeld – located in the *Middle Ahr Valley*. Ahrbrück is the location where our eyewitness account took place, and evidence relates to. Ahrbrück was largely destroyed by the flood. Several houses were washed away and several people died. The district of Brück was hit particularly hard. The Ahr bridge, which connects the districts of Ahrbrück and Brück, was cut through by the masses of water and debris. Our autopsy sample is stratified by a mix of data – existent landscape, weather, etc. -, available maps and data, public footage and photos, personal footage and photos, and our own modelling.

3.1 Before the Flood

Existent landscape and particular weather patterns constitute principal factors for flood events. The oldest strata, are the geology, the related topography (Figure 4), as well as the settlement and infrastructure patterns of the investigation area. The Devonian rock of the Ahr valley, is steep and generally impermeable to water. Heavy rains typically flow down into the valley without significant percolation (MEYER 1993). The tributaries of the Ahr river are steep. This turns the Ahr valley into a funnel, in which heavy rain collects very quickly and forms large masses of directed water. That is why, since Romanticism, the Ahr river is considered as *the wildest daughter of the Rhine*. Historically, in the steep and narrow Ahr valley, people founded settlements where it seemed least costly and most beneficial – on the valley floor, close to the river. The associated urban infrastructure is also largely to be found there (Figure 5).

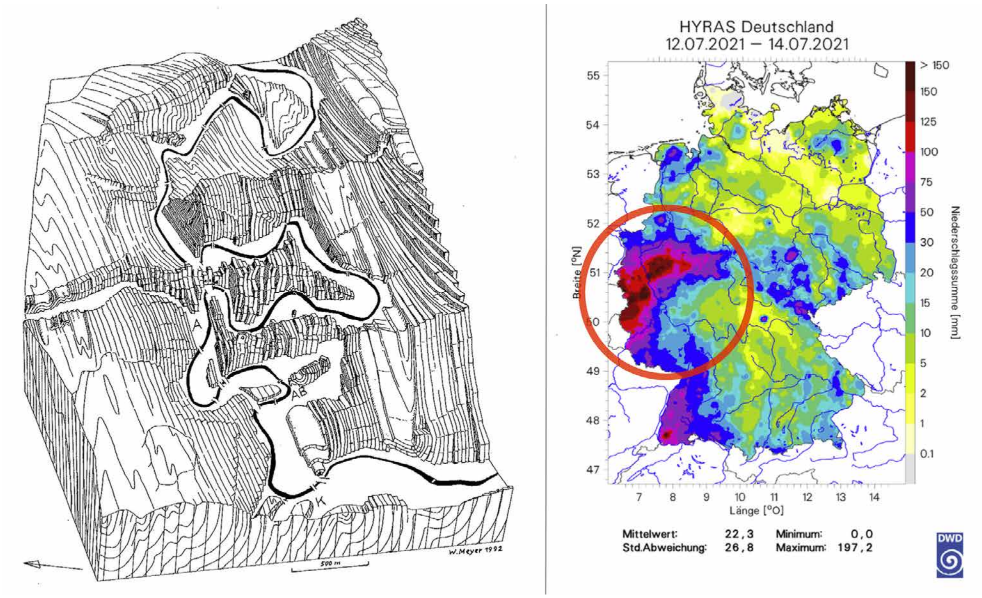

Fig. 4: Left: Geological block diagram of the area around Altenahr (MEYER, 1992). Right: Precipitation analysis for the duration level 72 hours until 15.07.2021, 8:00 a.m. CEST (Source: DWD, 2021).

Fig. 5: Settlements and infrastructure at the valley bottom. Left: Historic view of Altenahr and the White Cross (Snapshots Of The Past, 2007). Right: Ahr valley photographed from above (Ralfk, 2002).

Before the 2021 flood, little attention has been given to an older floodplain map of the Ahr (Figure 6), published by the Structure and Approval Directorate North, of the Water Management Authority Rhineland-Palatinate in 2005, and revised in 2014 (WATER MANAGEMENT AUTHORITY RHINELAND-PALATINATE 2014). The weather was decisive, before and during the flood. *Due to the extensive and persistent heavy precipitation, large parts of river catchment areas were irrigated. The water collected and was partly channeled in the narrow* *river valleys. The enormous amounts of rain, but above all the orographic conditions and saturated soils, led to a potentiation of the subsequent damage effect* (German Weather Service 2021, translated).

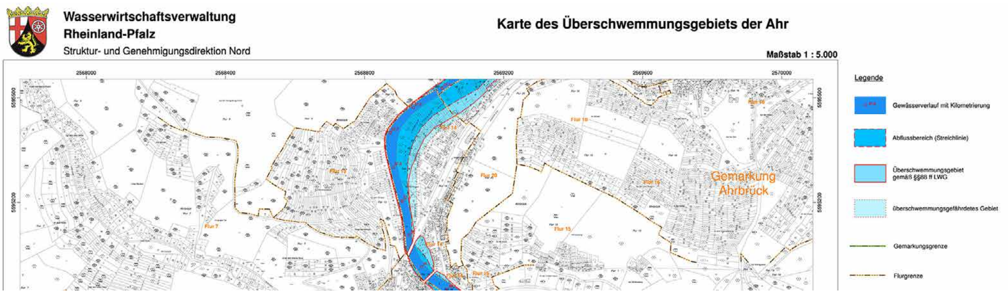

Fig. 6: Clipping of a sheet of the previously valid Ahr floodplain map (until 3 Oct, 2021), showing floodable areas of the district of Ahrbrück. It was published in 2005, and revised in 2014 (WATER MANAGEMENT AUTHORITY RHINELAND-PALATINATE, 2014).

3.2 During the Flood

The contextual factors of meteorology and geology that were significant for the settlement of the region before the flood also affected the region during the flood. In our approach to a landscape and flood autopsy, we consider the dramatic moment of the flood itself as a period of time for which, in retrospect, mainly other factors should be recalled beyond the hard facts of geology, meteorology, and the like. The brutal experience of eyewitnessesfrom immediate destruction of houses, cars, infrastructure, etc., up to the extinguishing of human life – is not usually considered relevant for professional design purposes, and thus not combined with precipitation data, gauge values, and other 'hard facts' in an analytical review. Therefore, such accounts are quickly lost from memory and retrospection. People's distress, helplessness, horror and fear of death cannot be measured and translated into hard facts, but we are convinced that these factors should be integrated into design decision-making processes after a flood. That is why we integrate – into our model of the post-flood autopsy – our own eyewitness account and that of others. While the description of the flood event, in academic language should sound neutral and unemotional, such professional aloofness and detachment are not necessarily helpful regarding the vital decisions that follow in a post-flood adaptation process – conducted by human beings, for human beings. For example, the prosaic account of the German Weather Service describing the most severe flood event that ever occurred in the Ahr valley, may contribute to an underestimation of the consequences of planning and design. Therefore we suggest that future models of post-flood autopsies should integrate all kinds of available eyewitness accounts, footage, and documentation. The resulting bigger, very complex picture is relevant for further decision making, having a relevance that an abstract flood line on a map lacks. During the flood, we were able to document the moment when the bridge in Ahrbrück was obstructed (Figure 7). As a result, the water rose rapidly, the water masses tore their own way, and new flow channels formed. Houses were suddenly exposed to water currents that they could not withstand. Amid the flood peak, a resident of the eastern side valley of Ahrbrück let his camera drone fly (STUKOWSKI 2021). His video shows how our neighbours' house is suddenly uplifted and floats away, drifting down the raging river with four people on the roof. The full picture of the family's fate emerged when it was confirmed that the father survived with one child, and the mother and the other child had drowned in the floodwaters. Some might say that a narrative like that does not belong in a scientific-technical work. We do not agree with such a point of view. Because we observe, like in a déjà vu, that planning problems that have demonstrably led to destruction and casualties are now being restored in the same form shortly after the flood, as by the almost faithful reconstruction of bridges (Figure 7) that have failed during the flood.

Fig. 7: Left: The clogging Ahr bridge in Ahrbrück, during the flood, before it was overflooded and destroyed (Photo: J. Rekittke, 2021). Right: An identically constructed Ahr bridge in Rech, further downstream, clogged and destroyed during the flood, but already being reconstructed without flood adaptation (Photo: SWR, 2021).

3.3 After the Flood

We checked the latest figures published by the Supervision and Service Directorate (ADD 2021) of the federal government. We even incorporated the moment when politicians with drooping heads came to the disaster area (Figure 8). They showed themselves shocked, back then, but have since advocated to turn back the wheel of time, almost entirely. We use the latest Ahr floodplain map, which serves as basis for planning, and impressions of our own continuing documentation, taking place where the flood had hit us.

Fig. 8: Left: After the flood, Chancellor A. Merkel and Rhineland-Palatinate Prime Minister M. Dreyer visit the village of Schuld (Photo: W. Rattay/Reuters, 2021). Right: The Mayor of the village of Schuld, on the day of Merkel's visit (Photo: C. Stache/dpa, 2021).

After the disaster, two national 'Future Conferences' took place. Politicians announced funding and green light for reconstruction, while scientists were disappointed. Reimund Schwarze from the Helmholtz Center for Environmental Research (UfZ), explains that funds are badly invested if they are only used for reconstruction, not for adaptation to future extreme weather (GÖTZE 2021).

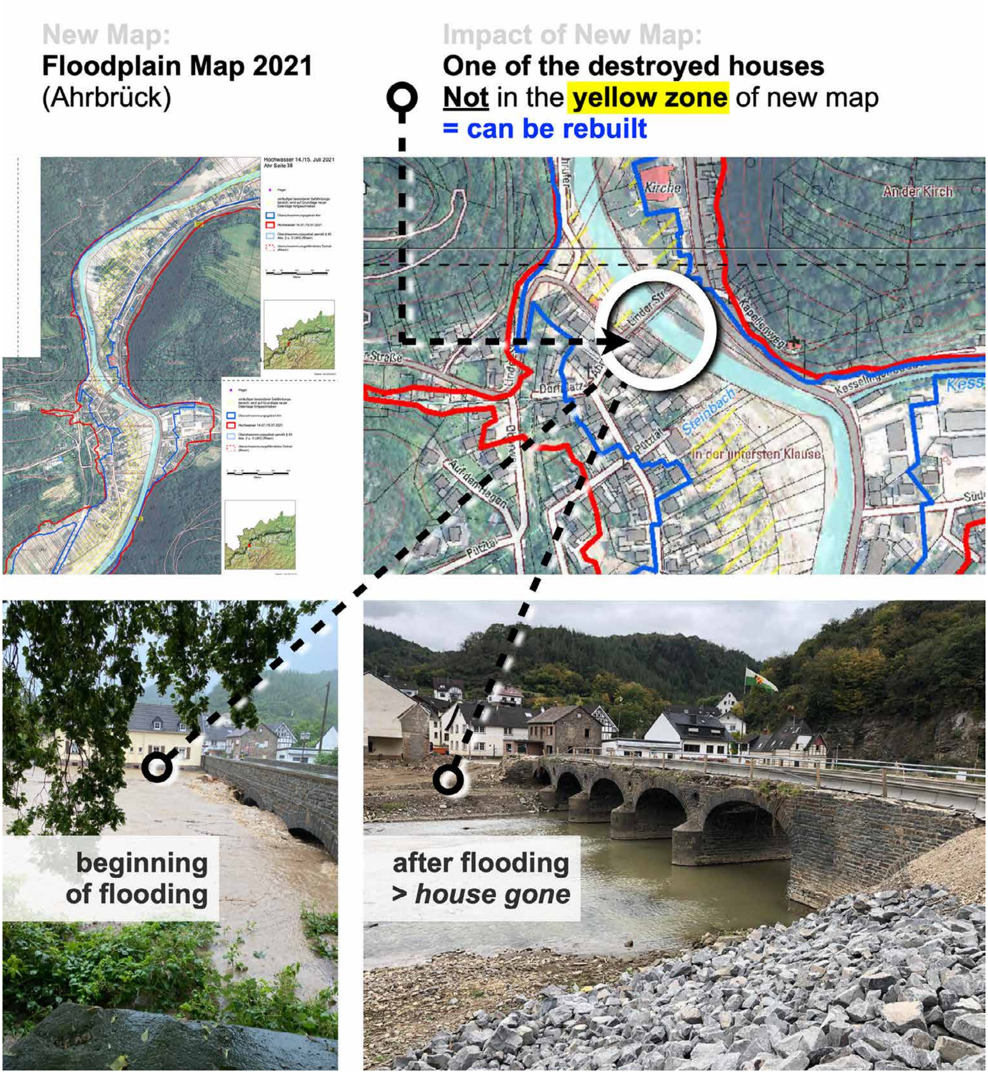

Fig. 9: Top: New map of Ahr floodplain. Red line = Flood in July 2021. Blue line = Ahr floodplain by law (since October 2021). Yellow hachures = Special hazard area, where rebuilding may not occur. Bottom: Though destroyed by the flood, the house next to the damaged Ahr bridge in Ahrbrück lies beyond the yellow zone, thus may be rebuilt (Map: WATER MANAGEMENT AUTHORITY RHINELAND-PALATINATE, 2021. Photos: Left: J. Rekittke, 2021; Right: V. Rekittke, 2021).

In October 2021, the federal Water Management Authority published new maps of the Ahr floodplain (WATER MANAGEMENT AUTHORITY RHINELAND-PALATINATE 2021). The new floodplain map generates irrefutable and long-term consequences (Figure 9). Based upon this map most homeowners have the assurance that they can renovate their home, remaining in the same flood-affected location (SWR AKTUELL 2021b). Other available documentation shows that in some places the new flow path of the water, post-flood, brings further structural compromises.

4 Digital Post-disaster Inspection and Superimposition

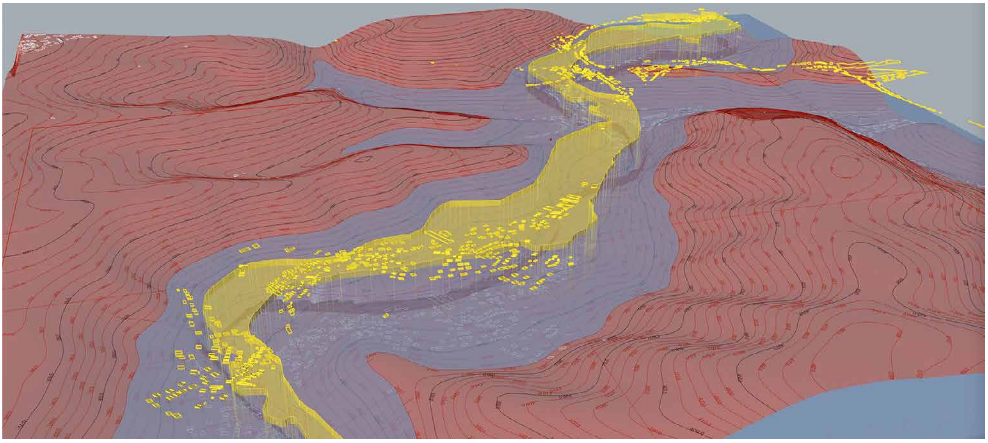

Fig. 10: Basic autopsy model, showing the recent Ahr floodplain categories, and all relevant buildings (Model: Y. Ninsalam, 2021)

Within the context of the disaster, the systematic search for the underlying pathology of the flood event remains secondary to the timeliness of post-recovery activities. As a result, the trauma caused by the event is being retouched through the quick redrawing of cadastral boundaries that guide recovery processes. These official map series are widely constructed remotely through the secondary reinterpretation of the past events using high-resolution satellite imagery and fail to take into consideration primary accounts of the flooding event. An innovation of this research is to amplify these firsthand accounts using a digital autopsy, and to visually superimpose secondary planning criteria with primary sources like eyewitness accounts, footage, and imagery.

Virtually all victims of the flood disaster that we met on-site, expressed, though being eyewitnesses themselves, the 'inconceivability' of what had happened during the flood. Therefore, the digital autopsy illuminates the flood landscape from every conceivable angle. It not only uses government-endorsed technical drawings, but open-source spatial data and a fragmented collection of eyewitness footage from both aerial and terrestrial sensors. Information made public through social media platforms are translated into a spatial common ground, in *Rhinoceros 3D* (MCNEEL & ASSOCIATES 2022), to reveal the disparity in the interpretation and recounting of the events that unfolded. By geolocating the diverse eyewitness account footage, this serves as a method to uncover and reconstruct moments that cannot be imaged and imagined using remotely drawn floodplain maps. We materialize this evidence onto a globally available 30-metre resolution digital elevation of the site derived from Shuttle Radar Topography Mission (NASA SRTM, 2013) data and building information from Open-StreetMap (PLANET OSM, 2021). Using open-source data sets has become the preferred imaging modality employed to position cadastral data onto topographical information and is aided but not limited by using *Grasshopper* plugins such as *Docofossor* (HURKXKENS & BERNHARD 2019) and *Groundhog* (BELESKY 2017) to visualize the relevant elevation and corresponding environmental information. Another layer of information is based on mapping data used by the Copernicus EMS Rapid Mapping Service to monitor the flood evolution (COPERNICUS EMERGENCY MANAGEMENT SERVICE 2021). It shows the graded damage assessment of the area. The flood trace, produced from the thematic layer map, was digitally reproduced. These survey lines were digitized by the authors into *Rhinoceros 3D* (MCNEEL & ASSOCIATES 2022) (Figure 10). We continue to build layers of information from various official sources, including from the Water Management Authority (WATER MANAGEMENT AUTHORITY RHINELAND-PALATINATE 2021). Additional layers of information illustrate the eyewitness accounts (Figure 11). A colorized 2.2-million-point cloud was generated from 206 images extracted from amateur drone footage (STUKOWSKI 2021). Through aerial photogrammetry reconstruction with *Pix4DMapper*, we were able to map external camera parameters for x, y, z during the post-processing of the images, to illustrate the flight path during the event (in green). The point clouds were added into the scene using the *Point Cloud Components* plugin (LIN & GIROT 2014) to illustrate the altered capacities of the landscape during the flood.

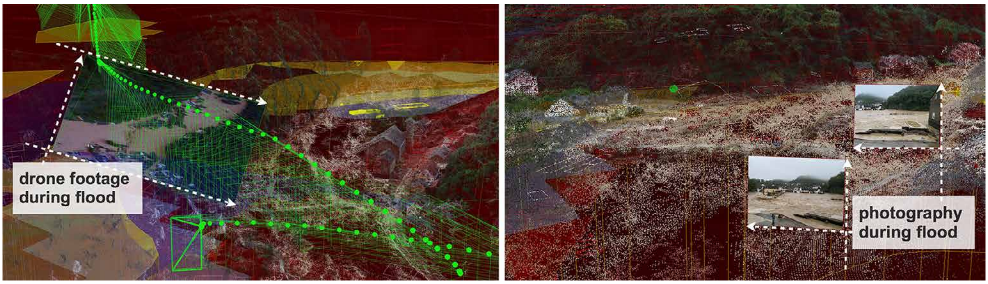

Fig. 11: Advanced autopsy model, showing included detailed evidence during the flood, from drone footage (left), and own documentation (right) (Model: Y. Ninsalam, 2021; Drone footage: STUKOWSKI, 2021; Photos: J. Rekittke, 2021).

Despite augmenting the official cadastral dataset with aggregated personal accounts of the incident, a question posed by one of our reviewers made us return to our title and initial point of departure, in taking inspiration from what *what3words* has to offer as a modality to rethink how spatial information is presented. The reviewer asked how our own autopsy might survive expectable digital amnesia? How can this *flood.landscape.autopsy* be made available to the public, so that others can learn from it? Perhaps a change in documenting personal accounts post-disaster should be taken, similar to the approach that *what3words* seeks to deliver. A statement on their website reads: “Street addresses weren’t designed for 2021. They aren’t accurate enough to specify precise locations, such as building entrances, and don’t exist for parks and many rural areas. This makes it hard to find places and prevents people from describing exactly where help is needed in an emergency" (WHAT3WORDS.COM 2022). Based on our experience, only the visual superimposition of such precise location information with relevant planning information will lead to continued memorisation and sustainable design action (Figures 12 and 13). Recollection and remembrance should last at least as long as it takes for future-relevant design decisions to be made and implemented.

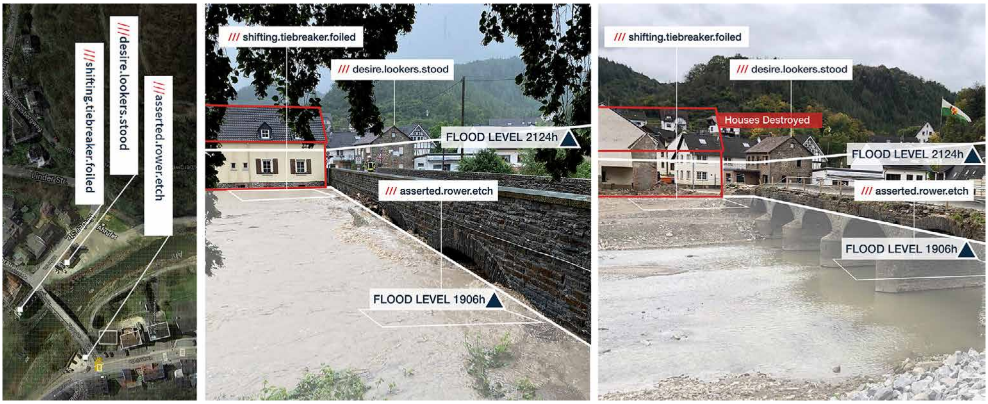

Fig. 12: Only the identification of specific and precise locations, paired with an overlay with related precise past information, does justice to the complexity of a flood disaster and the necessary design responses (Graphics: Y. Ninsalam, 2021; Photos: J. Rekittke, 2021).

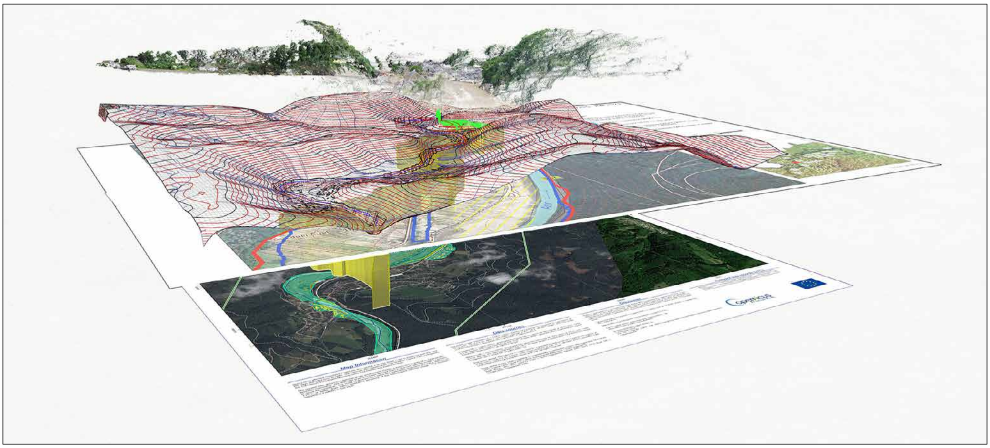

Fig. 13: The visual and layered superimposition of precise location information with relevant planning information will lead to continued memorisation and sustainable design action. Layers (top to bottom): 1) Point cloud (also standing for documentation during flood, AR, etc.); 2) Landscape Model; 3) New Floodplain Maps (2021); 4) Post-disaster Flood Map (Copernicus) (Graphics: Y. Ninsalam, 2022).

We continue to question the degree of resolution captured in the new development lines redrawn after the Ahr valley flood in 2021 (WATER MANAGEMENT AUTHORITY RHINELAND-

PALATINATE 2021), lines that could have been remotely drawn for any place in the world, eventually preventing people from considering exactly what happened and what should be done. Serious effort is continuously needed. Our proposed framework demands higher complexity, expressed in terms of a multilayered data stack (Figure 14).

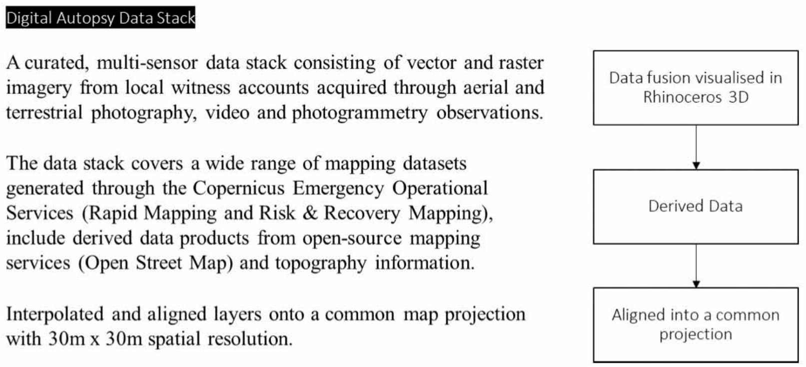

Fig. 14: Digital Autopsy Data Stack (Graphics: Y. Ninsalam, 2022)

5 From Conventional to Prospective Digital Landscape

Where a conclusion or outlook would be expected, we instead formulate an aspiration. Without further learning and preparation, we will not be able to gird our loins by leaving behind conventional digital landscape work, in the shape of common digital modelling, imaging, etc., and moving towards methods and processes that build upon how quantitative geospatial data are expressed qualitatively. Taking *what3words* as an example on how longitudinal and latitudinal coordinates are converted into a three-word address, which seems to be particularly suited for disaster-related planning and design work. While the superimposition of memories can be achieved through augmented reality – with the goal of bridging the gap between the real world and virtual data, by using head-mounted displays showing digital content like images, videos, animations etc. on a user's view of the real world (PEDDIE 2017) – such technology becomes superficial if the immersive retrospection leads to the repeating of the same mistakes. Therefore, we consider it necessary to augment specifically the high abstraction level of widely unsuccessful material, such as conventional flood plain maps, with genuine impressions of past or future reality in post-disaster design processes. Further work in embedding personal accounts to three-word addresses, using the *what3words* application programming interface with geospatial platforms, such as ArcGIS or QGIS (OLAYA 2016), to utilize the geo-coder that turns geographic coordinates into three-word addresses and vice-versa, are currently underway. Indispensable post-disaster adaptation to changing climatic conditions is probably the right driver to practice genuine digital landscape architecture for meaningful, better, and sustainable corollaries.

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